CLAIMS

What is claimed is:

1. A reciprocating fuel pump system comprising:

a housing assembly including a drive section and a pump section;

a drive assembly disposed in the drive section, the drive assembly including a permanent magnet and a coil assembly having a winding comprising a first lead and a second lead and disposed within the central volume of the drive section adjacent to the permanent magnet and movable reciprocally axially along a central axis upon application of alternating current power to the winding;

a pump member secured to and movable reciprocally with the coil assembly, the pump member extending into the pump section to produce pressure variations in the pump section during reciprocal movement to draw fuel into the pump section and to express fuel therefrom; and

a reciprocating circuit coupled to the coil assembly and including a storage capacitor and a plurality of switches, the first lead of the coil assembly coupled to the voltage source and the second lead of the coil assembly coupled to the storage capacitor through at least one of the plurality of switches.

2. The pump system of claim 1, wherein the permanent magnet at least partially surrounds a portion of the central volume and extends generally along a central axis, and wherein the coil assembly is disposed radially within the portion of the central volume.

3. The pump system of claim 1, wherein the permanent magnet is disposed adjacent to an end of the drive section, and wherein the coil assembly is disposed between the permanent magnet and the pump section.

4. The pump system of claim 1, wherein the permanent magnet includes at least one magnet elements.

5. The pump system of claim 1, wherein the pump member includes a tubular member extending from the coil assembly through a sealed bore into the pump section.

6. The pump system of claim 1, wherein the pump section includes an inlet check valve and an outlet check valve, the inlet and outlet check valves being actuated by pressure variations produced by reciprocal movement of the pump member in the pump section.

7. The pump system of claim 1, further comprising a nozzle in fluid communication with the pump section for expressing pressurized fuel from the pump section.

8. The pump system of claim 1, wherein the reciprocating circuit comprises a first switch, a second switch, and a third switch.

9. The pump system of claim 8, wherein the first switch is arranged in parallel with the second switch and further in parallel with the third switch.

10. The pump system of claim 8, wherein the reciprocating circuit is configured such that the coil assembly is in series between this voltage source and the plurality of switches.

11. The pump system of claim 10, wherein the reciprocating circuit is further configured such that the coil assembly is in series with each of the first switch, the second switch, and the third switch.

12. The pump system of claim 11, wherein the first switch is coupled to ground.

13. The pump system of claim 12, wherein the capacitor is coupled in series between the second switch and ground.

14. The pump system of claim 13, wherein the second switch comprises a diode.

15. The pump system of claim 14, wherein the first switch is coupled to a micro-controller.

16. The pump system of claim 15, wherein the third switch is coupled to a micro-controller.

17. A reciprocating fuel pump comprising:

a resonant drive system including a resonant coil assembly having a first lead and a second lead and a permanent magnet, one of the resonant coil assembly and the permanent magnet being disposed in a fixed position and the other of the resonant coil assembly and permanent magnet being movable reciprocally by application of electrical current from a reciprocating circuit coupled to the coil assembly, the reciprocating circuit including a storage capacitor and a plurality of switches, the first lead of the coil assembly coupled to a voltage source and the second lead of the coil assembly coupled to the storage capacitor through at least one of the plurality of switches, to the resonant coil assembly, the drive system further comprising a drive member secured to and movable reciprocally with either the coil assembly or the permanent magnet;

a pump assembly adjacent to the drive system, the drive member extending into the pump assembly for generating increases and decreases in fluid pressure within the pump assembly during reciprocal movement to draw fuel into the pump assembly and to express fuel therefrom.

18. The pump of claim 17, wherein the permanent magnet is disposed in a fixed location within the drive system at least partially surrounding a central volume thereof

and extending generally along a central axis, and wherein the coil assembly is disposed movably within the portion of the central volume.

19. The pump of claim 17, wherein the permanent magnet is disposed in a fixed location adjacent to an end of the drive system, and wherein the coil assembly is disposed between the permanent magnet and the pump assembly.

20. The pump of claim 17, wherein the permanent magnet includes at least one magnet elements.

21. The pump of claim 17, wherein the drive member includes a tubular member extending from the coil assembly through a sealed bore into the pump assembly.

22. The pump of claim 17, wherein the pump assembly includes an inlet check valve and an outlet check valve, the inlet and outlet check valves being actuated by pressure variations produced by reciprocal movement of the drive member during operation.

23. The pump of claim 17, further comprising a nozzle in fluid communication with the pump assembly for expressing pressurized fuel from the pump assembly.

24. The pump of claim 17, wherein the reciprocating circuit comprises a first switch, a second switch, and a third switch.

25. The pump of claim 24, wherein the first switch is arranged in parallel with the second switch and further in parallel with the third switch.

26. The pump of claim 24, wherein the reciprocating circuit is configured such that the coil assembly is in series between the voltage source and the plurality of switches.

27. The pump of claim 26, wherein the reciprocating circuit is further configured such that the coil assembly is in series with each of the first switch, the second switch, and the third switch.

28. The pump of claim 27, wherein the first switch is coupled to ground.

29. The pump of claim 28, wherein the capacitor is coupled in series between the second switch and ground.

30. The pump of claim 29, wherein the second switch comprises a diode.

31. The pump of claim 30, wherein the first switch is coupled to a micro-controller.

32. The pump of claim 31, wherein the third switch is coupled to a micro-controller.

33. A reciprocating pump comprising:

a drive system including a permanent magnet and a resonant coil assembly, the coil assembly having a first lead and a second lead and being energizable by application of electrical current from a reciprocating circuit coupled to the coil assembly, the reciprocating circuit including a storage capacitor and a plurality of switches, the first lead of the coil assembly coupled to a voltage source and the second lead of the coil assembly coupled to the storage capacitor through at least one of the plurality of switches to cause reciprocal movement of a drive member; and

a pump assembly disposed adjacent to the drive system, the pump assembly including means for admitting a supply of fluid into an inner volume of the pump assembly, means for pressurizing the inner volume by reciprocal movement of the drive member, and means for expressing pressurized fluid from the inner volume.

34. The pump of claim 33, wherein the permanent magnet is disposed in a fixed location within the drive system at least partially surrounding a central volume thereof and extending generally along a central axis, and wherein the coil assembly is disposed movably within the portion of the central volume.

35. The pump of claim 33, wherein the permanent magnet is disposed in a fixed location adjacent to an end of the drive system, and wherein the coil assembly is disposed between the permanent magnet and the pump assembly.

36. The pump of claim 33, wherein the permanent magnet includes at least two magnet elements.

37. The pump of claim 33, wherein the drive member includes a tubular member extending from the coil assembly through a sealed bore into the pump assembly.

38. The pump of claim 33, wherein the means for admitting a supply of fluid into an inner volume of the pump assembly includes a check valve biased into an open position and closed by an increase in pressure within the inner volume during operation.

39. The pump of claim 33, wherein the means for pressurizing the inner volume by reciprocal movement of the drive member includes a portion of the drive member.

40. The pump of claim 39, wherein the drive member is a tubular element and the means for pressurizing the inner volume includes a valve element which seats to seal an inner passageway of the drive member during a pressure stroke thereof.

41. The pump of claim 33, wherein the means for expressing pressurized fluid from the inner volume includes an outlet check valve biased into a closed position and opened by an increase in pressure within the inner volume during operation.

42. The pump of claim 33, further comprising a nozzle in fluid communication with the pump assembly for expressing pressurized fluid from the pump assembly.

43. The pump of claim 33, wherein the reciprocating circuit comprises a first switch, a second switch, and a third switch.

44. The pump of claim 43, wherein the first switch is arranged in parallel with the second switch and further in parallel with the third switch.

45. The pump of claim 43, wherein the reciprocating circuit is configured such that the coil assembly is in series between the voltage source and the plurality of switches.

46. The pump of claim 45, wherein the reciprocating circuit is further configured such that the coil assembly is in series with each of the first switch, the second switch, and the third switch.

47. The pump of claim 46, wherein the first switch is coupled to ground.

48. The pump of claim 47, wherein the capacitor is coupled in series between the second switch and ground.

49. The pump of claim 48, wherein the second switch comprises a diode.

50. The pump of claim 49, wherein the first switch is coupled to a micro-controller.

51. The pump of claim 50, wherein the third switch is coupled to a micro-controller.

52. A reciprocating circuit comprising:

a capacitor configured to be coupled to a voltage source through a plurality of switches; and

a plurality of switches coupled to the voltage source and configured to facilitate charging of energy in a coil assembly, discharging of the energy in the coil assembly, charging of the capacitor with the discharged energy from the coil assembly, discharging of the energy in the capacitor, and recharging of the coil assembly with energy discharged from the capacitor.

53. The reciprocating circuit of claim 52, comprising a first switch, a second switch and a third switch.

54. The reciprocating circuit of claim 53, wherein the first switch is arranged in parallel with the second switch and further in parallel with the third switch.

55. The reciprocating circuit of claim 54, wherein the coil assembly is in series between the voltage source and the plurality of switches.

56. The reciprocating circuit of claim 55, wherein the coil assembly is placed in parallel with the first switch, the second switch and the third switch.

57. The reciprocating circuit of claim 56, wherein the first switch is coupled to ground.

58. The reciprocating circuit of claim 57, wherein the capacitor is coupled in series between the second switch and ground.

59. The reciprocating circuit of claim 58, wherein the second switch comprises a diode.

60. The reciprocating circuit of claim 59, wherein the first switch is coupled to a micro-controller.

61. The reciprocating circuit of claim 60, wherein the third switch is coupled to a micro-controller.

62. A method of producing a reciprocal motion in a fuel pump comprising the steps of:

(a) providing a first, a second, and a third switch;

(b) closing the first switch, opening the second switch, and opening the third switch;

(c) producing a current using a voltage source;

(c) providing a path from the voltage source to ground through a coil assembly and through the first switch;

(e) opening the first switch;

(f) storing a charge in the coil assembly;

(g) providing a path from the voltage source to ground through the coil assembly through the second switch and through a capacitor;

(h) closing the second switch;

(i) discharging the energy stored in the coil assembly into the capacitor;

(j) storing the energy in the capacitor;

(k) opening the second switch and closing the third switch;

(l) discharging the energy stored in the capacitor into the coil assembly.

63. A method of displacing fuel in a pump system comprising the steps of:

(a) positioning a reluctance gap coil within a solenoid housing;

(b) mounting an armature moveably within a housing and securing the armature to a guiding member;

(c) energizing the coil by providing a current through the coil in a first direction;

(d) actuating the coil to drive the armature in a downward direction toward a reluctance gap;

(e) de-energizing the coil by providing a first electrical path from the coil to a capacitor which is configured to store the energy which is dissipated from the coil;

(f) de-energizing the capacitor by providing a second electrical path from the capacitor to the coil by which current is driven through the coil in a second direction; and

(g) actuating the coil to drive the armature in an upward direction away from the reluctance gap.

64. A method of displacing a pumping assembly comprising the steps of:

(a) energizing a coil assembly to displace a pumping assembly in a first direction;

(b) storing energy in a capacitor coupled to the coil assembly; and

(c) discharging the energy from the capacitor to the coil assembly to displace the pumping assembly in a second direction opposite from the first direction.

65. The method of claim 64, wherein the energy is first stored in the coil assembly, and then discharged from the coil assembly to charge the capacitor.